Paper Spray: Universal Ambient Ionization Source for the Detection of Chemical and Biological Agents

Trevor Glaros[1], J. Michael Nilles[2], Theresa R. Connell[2],Paul Demond[2], Jennifer W. Sekowski[1], Nicholas Manicke[3], Justin Wiseman[4]

[1]Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD, [2]Excet Inc. Springfield, VA, [3]Indiana University-Purdue University Indianapolis, Indianapolis, IN, [4]Prosolia Inc, Zionsville, IN

Abstract

Paper spray ionization coupled with mass spectrometry has the potential to be the first universal platform capable of detecting the three major classes of threats (chemical, biological, and explosives). Ambient ionization is a form of ionization which occurs directly outside of the inlet to the mass spectrometer in normal atmospheric conditions. This family of techniques typically requires little to no sample preparation and has proven to be highly effective for the detection of pharmaceutical drugs, illicit chemicals (drugs of abuse and explosives), and analysis of samples from complex matrices including surfaces, food, blood, urine, and tissue. Several ambient ionization sources have been commercialized and well characterized including Direct Analysis in Real Time [DART-MS; JEOL and IonSense], Desorption Electrospray Ionization [DESI-MS; Prosolia Inc], and paper spray ionization [PS-MS; Prosolia Inc.]. This work aims to show that paper spray ionization can successfully detect and quantify a variety of chemical signatures directly from surfaces, whole blood, and urine. Furthermore, we aim to generate preliminary evidence that demonstrates that PS-MS can also detect toxins or biological signatures making it the first potentially fieldable platform to successfully span the chemical-biological detection arena.

Paper Spray Ionization

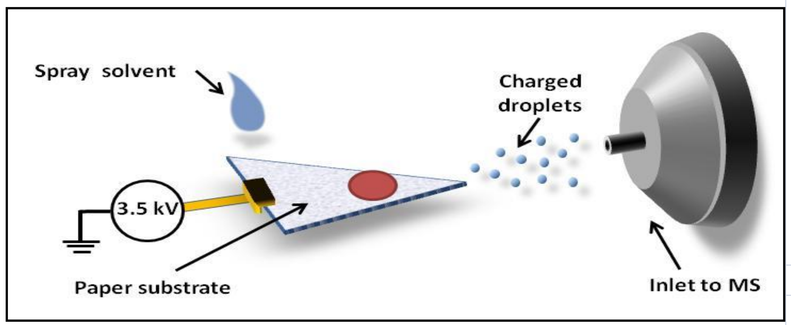
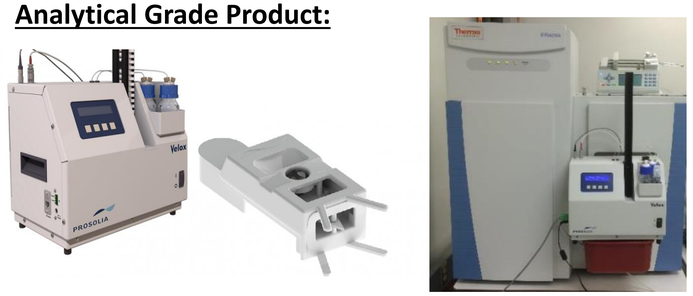


Figure 1. The analyte (red), such as blood and urine, can be spotted on the paper, or the paper can be used as a wipe to sample a surface.

Commercialized by Prosolia Inc.

Analytical Grade Product:



Envisioned Fieldable Unit:

Li, Linfan, et al. "Mini 12, Miniature Mass Spectrometer for Clinical and Other Applications Introduction and Characterization." Analytical chemistry 86.6 (2014): 2909-2916.

Comparison to Current State-of-the-Art

Logistical Burden [↑]	Parameter	PS-MS (This Study)	DART-MS	DESI-MS	LC-MS	GC-MS
	Electrical Requirement	↑	↑↑	↑↑	↑↑↑↑	↑↑↑↑
	Purified Gas	NONE	↑↑	↑↑	↑↑	↑↑↑ Requires At Least Two Sources
	Solvent	25uL per sample (Only one Solvent Needed)	NONE	≥ 0.5L per day	≥ 0.5L per day	NONE
	Surface Detection	Complete Analysis Directly From Wipe	Wipe & Signifcant Manipulation at the Source	Wipe Material Considerations & Significant Manipulation at the Source	Preparation Required with Extraction	Preparation Required with Extraction
	Portability	+	+	+	-	-
	Throughput (per analysis)	~90 sec	~9 sec	~9 sec	≥ 10 min	≥ 10 min
	BioDetection	+	-	+	+	-

Current Body of Work

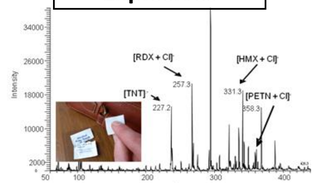
Illicit Drug Detection

Drug	Paper Spray LOD directly from DBS (ng/mL)
Amphetamine	1
Methamphetamine	0.3
MDA	2
MDMA	0.04
MDEA	0.3
Morphine	12
Cocaine	0.05
D9-THC	4

Limit of Detection (LOD) for a variety of illicit drugs from a single dried blood spot (DBS)

Espy, Ryan D., et al. "Paper spray and extraction spray mass spectrometry for the direct and simultaneous quantification of eight drugs of abuse in whole blood." *Analytical chemistry* 86.15 (2014): 7712-7718.

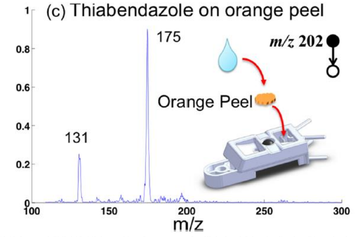
Explosives



Explosive	Dominant ion	LOD (MS/MS Mode)
PETN	$[M+Cl]^-$	250 pg
HMX	$[M+Cl]^-$	200 pg
RDX	$[M+Cl]^-$	5 ng^{-1}
Tetryl	$[M+Cl]^-$	1 ng
TNT	$[M]^-$	500 pg

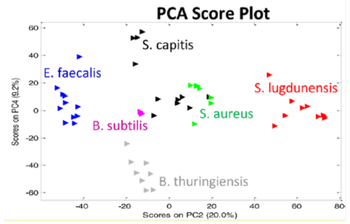
Manicke, Nicholas., et. al. Unpublished.

Pesticides



Li, Linfan, et al. "Mini 12, Miniature Mass Spectrometer for Clinical and Other Applications Introduction and Characterization." *Analytical chemistry* 86.6 (2014): 2909-2916.

Bacterial Fingerprinting



Hamid, Ahmed M., et al. "Rapid discrimination of bacteria by paper spray mass spectrometry." *Analytical chemistry* 86.15 (2014): 7500-7507.

Goals

FY16: Establish Paper Spray Capability and Validate at ECBC

A. General Compound and Matrix Survey
B. Establish LOD for militarily relevant compounds/simulants
C. Establish potential for bio-detection
D. Evaluation and integration of a surface wipe

FY17: Validation of Chemical and Biological Threat Materials

A. Threat compound and matrix survey
B. LOD for militarily relevant compounds
C. Bio-agent detection

FY18: Fusion of Paper Spray ionization to state-of-the-art fieldable mass spectrometer and exploration for extending paper spray capabilities

A. Marriage of paper spray ion source to top fielded MS system
B. Evaluate performance in a relevant environment
C. Expand capabilities

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.